CONVECTIVE INDICES

(Last updated: 04/27/01)

Stabilities

K Index **(J. J. George, 1960)**	
< 20	None
20 to 25	ISOLD
26 to 30	FEW
31 to 35	SCT
> 36	SCT to NMRS, Heavy Rain Potential

Vertical Totals **(Miller, 1972)**	
≥ 26	TS possible

Cross Totals **(Miller, 1972)**	
< 18	TS Unlikely
18 to 19	ISOLD to FEW
20 to 25	SCT
26 to 29	SCT to NMRS
≥ 30	NMRS

Total Totals **(Miller, 1972)**	
< 44	None
44 to 45	ISOLD to FEW
46 to 51	SCT

52 to 55	SCT to NMRS
> 56	NMRS

Lifted Index (degrees C)	
0 to -2	Weak Instability
-3 to -5	Moderate Instability
-6 to -9	Strong Instability
< -9	Extreme Instability

Formula: Difference between a given saturated parcel temperature and the 500 mb environmental temperature.

- The more negative the number, the more unstable the environment.

SBLI.....LI calculated using surfaced based parcel

MULI....LI calculated using a parcel from the pressure level that results in the Most Unstable value (lowest value) of LI possible

MLLI....LI calculated using a parcel consisting of Mean Layer values of temperature and moisture from the lowest 100 mb above ground level.

Convective Available Potential Energy (CAPE) (J/kg)	
0 to 999	Marginal Instability
1,000 to 2,500	Moderate Instability
2,500 to 4,000	Strong Instability
> 4,000	Extreme Instability

Formula: The positive area on the sounding between the LFC and the Equilibrium Level

- Not a true measure of instability, just available energy

- Can vary drastically on the mesoscale depending on surface heating, moisture, and thermal advection

- Stensrud et al (1997) stated that any thunderstorm that develops in an environment > 4,000 J/kg should be considered extremely dangerous.

SBCAPE........CAPE calculated using a Surface based parcel

MUCAPE......CAPE calculated using a parcel from a pressure level that results in the Most Unstable CAPE possible

MLCAPE.......CAPE calculated using a parcel consisting of Mean Layer values of temperature and

moisture from the lowest 100 mb above ground level.

Normalized CAPE

(J/kg)

Formula: CAPE/FCL where FCL is the depth of the Free Convective Layer.

Where $FCL = Z_{EL} - Z_{LFC}$ or $FCL = P_{EL} - P_{LFC}$

- CAPE does not always provide a good measure of buoyancy because it is a result of both depth of the FCL and the buoyancy. NCAPE scales the CAPE by depth to obtain a measure of the buoyancy and discriminate between soundings with large versus small aspect ration of CAPE.

- Units can be in (J/kg)/m which simplifies to m/s^2 or (J/kg)/mb

- Should examine both CAPE and NCAPE to get the full picture.

Lapse Rates

(degrees C)

- Greater instability as lapse rates approach dry adiabatic (9.8 $^oC/km$)

- Less than 5.5 $^oC/km$ is considered stable.

- Watch for $\geq 20^o$ delta T's between 500 and 700 mb

- Craven (2000) found that 6.7 $^oC/km$ was a useful lower limit on 63 of 65 major tornado outbreaks he studied.

TQ Index

(degrees C)

> 12	Lower troposphere is unstable and TSRA is possible outside of stratiform clouds.
> 17	Lower troposphere is unstable and TSRA is possible when stratiform clouds are present.

Formula: $(T_{850} + Td_{850}) - 1.7 (T_{700})$

- Used to assess low topped convection potential.

Delta theta-e (K) Atkins and Wakimoto (1991)	
$\geq$ 20	"Wet" microbursts likely to occur
$\leq$ 13	"Wet" microbursts unlikely to occur
Formula: Difference between the theta-e at the surface and the lowest theta-e in the mid levels - Based on a study of pulse type storms during the summer over the southeastern U.S. - Used to assess the potential for "wet" microbursts	

Shear Indices

Low Level Shear	
$\leq$ 22 kts (11 m/s)	Weak Shear (Bow echoes unlikely)
23 to 37 kts (12 to 19 m/s)	Moderate Shear (Bow echoes likely with the greatest threat of damaging winds)
$\geq$ 38 kts (20 m/s)	Strong Shear (Bow echoes likely with strongest winds remaining above the surface)
Formula: Magnitude of the vector difference of the 700 mb wind vector and the surface wind vector. - 0 to 3 km shear can determine if shear $\simeq$ cold pool. - Bow echoes and derechoes are associated with moderate to strong shear in the low levels (Przybylinski, 2000).	

Deep Layer Shear	
> 35 kts	Marginal for supercells
> 40 kts	Supercell development likely
Formula: Magnitude of the vector difference between the 450 mb wind vector and the surface wind vector. Can use the length of the hodograph between 0 and 6 km as an alternate. - 0 to 6 km shear can be used to determine supercell potential. - Not a good measure of low level rotation potential.	

- A deeper/shallower layer may be more appropriate for very deep or shallow storms. - Seems to be a reliable forecast tool (Thompson, 2000)

Bulk Richardson Number (BRN) Shear **(Strensrud et al., 1997, Davies 1998)**	
40 to 140 m^2/s^2	Potential for significant supercells
35 to 40 m^2/s^2	Potential for marginal supercell events (Thompson, 2000)
< 40 m^2/s^2	Associated with outflow dominated storms
(< 40 m^2/s^2 and SRH > 100 m/s associated bow echoes)	
Formula: Vector difference between the density weighted 0 to 6 km wind vector and the 0 to 500 m wind vector. - Shows fairly good utility in distinguishing storm morphology (supercell vs non-supercell), mid level mesocyclone intensity, and storm relative surface flow (Jahn and Doegemeier, 1996)	

Storm Relative Helicity (SRH)	
0 - 3 km SRH	
> 100 m^2/s^2	Supercells possible, high false alarm rate (Davies-Jones et al. 1990, Moller et al 1994)
> ~150 to 200 m^2/s^2	Right moving, significant supercells favored with large CAPE (Thompson, 2000)
> 300 m^2/s^2	Right moving, significant supercells favored with normal CAPE (Thompson, 2000)
> 500 m^2/s^2	Proposed minimum requirement for tornadoes to occur without augmentation from external boundaries (Markowski et al 1998b)
0 - 1 km SRH	
> 100 m^2/s^2	Increased threat of tornadoes with supercells.
Formula: The vertically integrated value of horizontal vorticity advection. It is a measure of how much streamwise vorticity is being ingested into a storm and is a measure of rotation potential. - Generally not as good as mean vertical shear in determining the potential for supercells since it requires a storm motion ahead of time (Weisman, 1996) - Varies by two to three orders of magnitude spatially. Can be much higher in the inflow of supercells (Markowski et al 1998a) - Once supercells are forecast by mean winds, then SRH can give an idea of how likely tornadoes are. - The larger the amount of SRH, the better the chance for tornadoes. However, there are no clear	

boundaries. - The term "effective" associated with storm relative helicity means attempts to estimate the value of SRH that is relevant to a particular storm. For example, a supercell forms or moves over an area where the most unstable parcels are located a couple of thousand feet above the ground, and stable air is located at ground level. The question then becomes "how much of the cool air can the supercell ingest and still survive?" SPC starts with the surface parcel level, and work upward until a lifted parcels CAPE value increase to 50 J/kg or more. From the level of a least 50 J/kg CAPE, the next 3 km or the vertical wind profile is used to calculate SRH.

Low Level SR Winds **(Thompson, 1998)**	
> 15 to 20 kts	Sustained Supercells
Formula: Magnitude of the vector difference of the wind vector in a given level or layer (e.g. 0 to 2 km) and the storm motion vector. - Should be only used a necessary but not sufficient parameter for supercells that will produce multiple or long lived (> 15 min) tornadoes.	

Anvil Level SR Winds **(Rasmussen and Straka, 1998)**	
< 25 kts	Almost always HP
< 35 kts	HP supercells favored
35 to 54 kts	Classic supercells favored
> 54 kts	LP supercell favored
Formula: Magnitude of the vector difference of the wind vector at 9 to 11 km AGL (~ 300 mb) and the storm motion vector. - Anvil SR level winds will help determine if hydrometeors get reingested into the updraft of a supercell. More hydrometeors ingested will cause the supercell to become more precipitation efficient and lean toward HP. - <u>If hydrometeors are ingested into a storm from other storms nearby or a cirrus canopy, then storms will lean toward HP regardless of anvil SR winds</u>.	

Storm Inflow	
>20 kts	Mesocyclone development is possible, tornado inflow requirement is met.
Formula: Magnitude of the vector difference of the wind vector in a given low level or low layer (e.g. 1000 m or 0-500 m) and the storm motion vector.	

- Yields the streamwise inflow a storm encounters as it moves through the atmosphere. Very important factor of SRH.

Mid Level SR Winds **(Thompson, 1998)**	
15 to 35 kts	Tornadic supercells
Formula: Magnitude of the vector difference of the wind vector in a given level or layer (e.g. 500 mb, 400-600 mb, 4-6 km) and the storm motion vector. - Should be only used a necessary but not sufficient parameter for supercells that will produce multiple or long lived (> 15 min) tornadoes.	

Combined Indices

Energy Helicity Index (EHI) **(Rasmussen and Blanchard, 1998)**	
> 1.5	significant tornadoes possible
Formula: EHI = (CAPE x SRH)/160,000 - Designed to pick up on significant tornado potential in both cool season (low CAPE, high shear environments) and warm season (high CAPE, low shear) environments.	

Bulk Richardson Number (BRN) **(Weisman and Klemp, 1984)**	
< 10	severe weather unlikely, shear too strong
10 to 50	supercells
> 35	multicells
Formula: CAPE/BRN Shear - Attempts to predict storm type by balance instability and shear - Weisman and Klemp (1984) said it was good discriminator between storm type, but Rasmussen and Blanchard refute this (1998) - Note overlap between 35 and 50	

- Can get HP supercells with values >50 in some extreme CAPE examples.

Vorticity Generation Parameter (VGP) (Rasmussen and Blanchard, 1998)	
0.2	increasing possibility of tornadic supercells
Formula: VGP=[S(CAPE)$^{1/2}$] where S is the hodograph length/depth - Involves the physical concept of tilting of vorticity	

Other Indices

Lifted Condensation Level (LCL)
- Lower LCLs imply greater moisture content in the atmosphere below the cloud base than if the LCL is higher. - In a study of nearly 3,000 studies in 1992, more than half the significant tornadoes were associated with LCL's below 2,600 ft (800 m) while more than half of the non-tornadic supercell soundings had LCLs above 4,000 ft (1200 m) (Rasmussen and Straka, 1998). Note there is overlap. - Edwards and Thompson (2000) found no strong or violent tornadoes occurring their database of 188 supercells with LCL's above 4,900 ft (1500 m).

Level of Free Convection (LFC)
- Level at which a lifted parcel begins a free acceleration upward to the equilibrium level. - Recent preliminary research suggest that tornadoes become more likely with supercells when LFC heights are less than 2,000 m (~6,500 ft) AGL (Thompson, 2001). - In a study of 43 isolated supercells higher LFCs (~7,200 ft) were associated with more LP and HP supercells than classic types (~5,600 ft). More instability above the LFC and less CIN below LFC. Rasmussen and Blanchard (1998) found that 75% of tornadic classic supercell enviornments had CIN < 21 J kg-1 and 60% of non- tornadic supercell environments had values greater than this.

LFC - LCL

- The height difference between the LFC and the LCL.

Supercell Composite Index

- An internal SPC index that is a summation of the 0-6 km shear, CAPE, and BRN shear.

- Each parameter is normalized by supercell "threshold" values. 0-6 km shear is divided by 40 kt, CAPE divide by 1000 J/kg and BRN shear is divided by 40 . For example, a 0-6 km shear of 60 kt, CAPE of 3000 J/kg, and BRN shear of 40 results in a supercell composite index of 9. Increasing values appear to be associated with an increased potential for supercells and tornadoes.

Wet Bulb Zero

(AWS/TR-79/006/Revised)

5,000 to 7,000'	small hail
7,000 to 9,000'	best for large hail
9,000 to 10,500'	large hail possible
> 10,500'	hail unlikely

Stensrud Tornado Potential

- Index used at SPC based on CAPE, SRH, and BRN Shear

- Highlights areas with a CAPE > 200 J/kg, SRH > 100 m^2/s^2, and BRN Shear between 30 and 100 m^2/s^2.

- STP values are assigned as follows: If BRN Shear is >40 m^2/s^2, the STP values are 30, 40, and 50 for SRH values > 200, 300, 400, respectively. STP values range from 5-20 when SRH is 100-200 m^2/s^2 and the BRN Shear is 30-40 m^2/s^2. Note that this index does NOT incorporate CAPE beyond the inital check for a CAPE value of at least 200 J/kg.

Line of Convergence vs. Mean Wind

(Thompson, 2000)

- You tend to get line segments of storms when the deep layer mean wind and shear vectors are parallel to the intiating boundary which typically occurs when wind profiles show pronounced back of mid level flow. In these cases, anvils tend to overlap and rain into adjacent storms on the boundary, which contributes to a larger and stronger pool of cold outflow. You can still get tornadic supercells in such profiles, but they're usually weak cap cases where isolated storms can form ahead of a cold front.

Supercell Likely Tornadic
- Parameter found in the volume browser - Davies (1996) found that in an examination of 60 cases, 72% of supercells in areas where BRN Shear values >60 m^2/s^2 coincided with EHI values of > 2.5 produced significant or long-lived tornadoes.

Limiting Factors	
Convective Inhibition (CINH) **- Convective inhibition is the negative area on a sounding found between the LCL and LFC.**	
$\leq$ 25 J/kg	Associated with significant tornadoes (Rassmussen and Blanchard, 1998)
~ 50 J/kg	Associated with derechoes (Przybylinski, 2000)
> 100 J/kg	Precludes thunderstorm development without significant forcing
Other thunderstorm inhibitors **(Johns and Doswell, 1992)**	
$\geq$ +12°C	700 mb temperature
$\geq$ 579 dm	1000-500 mb thickness
> 2°C	Cap strength

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